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A METHOD FOR CALCULATING GALILEAN SATELLITES DISTANCE FROM JUPITER USING IMAGE TECHNIQUE

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ABSTRACT

The purpose of this work is to describe the basic steps to measure the distance between the four Galilean moons (Io, Europa, Ganymede, and Calisto) and Jupiter using image technique. The Observation of Jupiter and its four large moons was carried out at 23 April 2014 in Baghdad (33.3°N, 44.43°E), University of Baghdad, College of science, using a telescope type Meade 12″ LX600-ACF mounted on the top of the Astronomy and space Department building with a camera model NIKON D7100. A MATLAB program was written for calculating the distance from the center of Jupiter to the center of each satellite. The average distance obtained from 6000×4000 size image at the observed night was found to be (Io=303409.8Km, Europa=1447505Km, Ganymede=3289074Km, and Callisto=855788Km). From this work it could be found that the image technique could be considered as an easy and fast way for finding the distances on the Jovian system.

KEYWORDS: Jupiter's Galilean Satellites, Image Technique, Jupiter, Moons

INTRODUCTION

The four major ("Galilean") satellites of Jupiter form a miniature Solar System, whose "years" are measured in days. Astronomers have monitored the motions of these worlds from Galileo's time to the present to improve their orbital models and to study the effects of tides on the movements of Io and Europa. The most accurate ways to measure the positions of these moons are by photographic astrometry with large telescopes and by CCD photometry of the eclipses of these bodies by the shadow of Jupiter [1].

As soon as Galileo observed these satellites, he understood the phenomenon of the eclipse occurring very often it was then easier to date each eclipse in order to get the period of the satellites than measuring the relative positions of the satellites. From Galileo until the beginning of the XXth century, Jovian eclipses of the satellites were extensively observed and were the basis for the building of the dynamical models of the motion of the Galilean satellites. The theories by Laplace (end of the XVIIIth century) and Sampson (beginning of the XXth century) is among the most achieved analytical models and is based on eclipses. However, the precision of these observations is limited by the refraction of light in the upper atmosphere of Jupiter determining the shadow cone. The progress of the direct astrometry thanks to the apparition of the photographic technique led to the decline of the use of eclipses. During the XXth century, the photographic technique was the main source of observations of the Galilean satellites [2].

In order of increasing distance from the planet, they are Io, Europa, Ganymede, and Callisto. Table 1 shows some physical data for the Galilean moons:

Table 1: Some Physical Properties of the Galilean Satellites [3]

Moon Name	Mean Distance from Planet (Km)	Orbital Period (Days)	Diameter (Km)	Density (Kg/M^3)
Io	421800	1.77	3643	3500
Europa	671100	3.55	3122	3000
Ganymede	1070400	7.15	5262	1900
Callisto	1882700	16.7	4800	1830

The Galilean satellites are easily viewed from Earth with the most basic of telescopes. So easy, in fact, that just about anyone with a fairly inexpensive telescope can deduce their revolution around Jupiter and measure their distance from Jupiter [3].

Research Measurements Procedure

The Observation was made at 23 April 2014 in Baghdad (33.3°N, 44.43°E), University of Baghdad, College of science, by using Meade 12″ LX600-ACF Telescope mounted in Astronomy and space Department with camera model NIKON D7100 which has the following properties:

Table 2

Sensor Resolution	24.1 Million
Sensor size	23.5×15.6 mm
Sensor pixel size	3.9µ
Sensor type	CMOS
Max shutter speed	1/8000 to 30 sec
Image size	6000×4000

The images taken at the night of observation was in different intervals of time and are displayed in figure 1

Figure 1: The Images Taken by NIKON D7100 at Different Time's Intervals for the Observed Night

To determine which moon was which, the date, time, and place of the images were input into Stellarium software [4]. Stellarium will display the Galilean moons with their names as shown in figure 1:

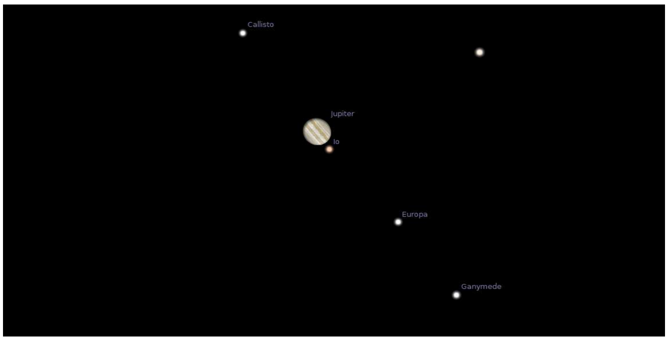

Figure 1: The Positions of the Galilean Satellites around Jupiter at the Observed Night Associated with their Names as they are Previewed by the Stellarium Program

To find the distance from each Galilean moon to Jupiter, a MATLAB program was written for this purpose. The algorithm of the program could be summarized as follow:

- Read the image which is previously stored in the computer memory.
- Convert the grayscale image to a binary image.
- Label the planet and it's satellites in the image, compute their centroids, and superimpose the centroid locations on the image, as shown in figure 2:
- Locate the (X,Y) of Jupiter as X_J and Y_J then the program will calculate the distance between the planet and each satellite using the formula:

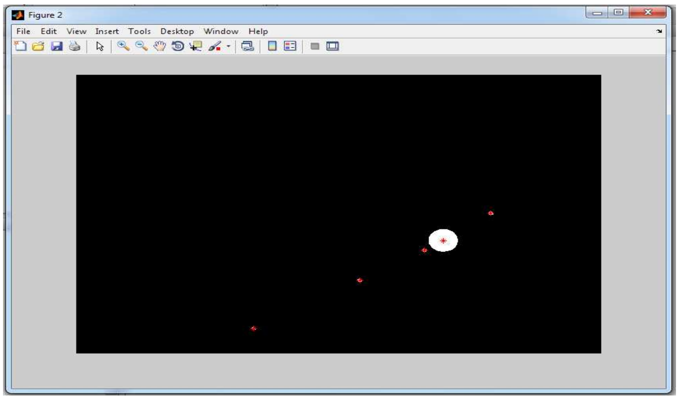

Figure 2: The MATLAB Program Will Superimpose the Centers Locations of the Planet and it's Satellites on the Image

$$D^2= ((X_J -X)^2 + (Y_J-Y)^2)^{.5}$$

The accuracy of the program on finding the centers were checked by loading on it a previous images of Jupiter and the four Galilean satellites whose their centers where determined by the ImageJ software and the results were almost the same.

The distance unit which is obtained by the image technique is (pixel). The arcseconds of the sky projected on to each pixel of the used telescope and CCD attached with it can be determined from the formula based on the pixel size of the CCD and the focal length of the telescope:

Arc-Seconds per CCD Pixel=206×Pixel Size (μm)/Focal Length (Mm) **(1)**

Since the pixel size of NIKON D7100=3.9µm and the focal length of the telescope=2438mm, thus the image scale =.329″/pixel.

By obtaining the distance between the satellites and Jupiter in arc seconds, the actual distance in (Km) could be determined by using simple trigonometry (figure 3).

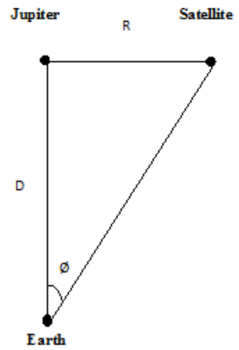

Figure 3: Simple Trigonometry to Determine the Actual Distance in (Km) between the Planet and its Satellite

$$R = D \times \tan(\text{Ø}) \quad (2)$$

Where

R=distance between satellite and Jupiter

in Km

D=Earth-Jupiter distance in Km

Ø=Projected angle in radians

The Earth-Jupiter distance at the observation date was determined from the stellarium software and it was found to be 5.484 AU (Note: 1 AU=1.496×10^{8}Km).

RESULTS AND DISCUSSIONS

There were some few difficulties during this work. The observed night was almost cloudy which prevented from taken more images so only three images with different time intervals were used in this paper. In order to reduce the execution time of the program, the image size was reduced three times its original size, and then the results obtained were multiplied by 3 to get the real distances. The results for the 6000×4000 image size are listed in table 3:

Table 3: Shows the Distances as it is Calculated in Km

Time	Io Dis. (Km)	Europa Dis. (Km)	Ganymede Dis. (Km)	Callisto Dis. (Km)
9:20:38	337733.4	1457104	3281059	876931.3
9:37:38	297749	1446527	3291488	850458.5
9:46:36	274746.9	1438884	3294676	839974.4
Average dis.	303409.8	1447505	3289074	855788

The results of the distance obtained from this work were almost far from the actual distances which were calculated from the standard equations that describe the motion of the Galilean Satellites (Meuus J., 1982). The results were also compared by previous similar work (N. Kelley, 2004) which its results also show that the measured distances

were fluctuated in values far from the actual values of distance for each moon. The reason behind this problem was owed to the parameter of the CCD camera (micron/pixel) and the other used equipments.

CONCLUSIONS

From this work it could be concluded that the distance between Jupiter and its Galilean satellites which are calculated by the image technique have some systematic error. But it stills an easy and fast method to measure the distances in the Jovian system. The MATLAB program which built to find the centers of Jupiter and its four large satellites has given a very good results when it compared by the programs that made for this purpose. The distance obtained from the image technique may also applied in Kepler's third equation to determine an approximate value for Jupiter's mass.

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